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THE FOOD-PRODUCING CROPS IN THE TROPICS

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ABSTRACT

The paper deals with some aspects of tropical agriculture, together with notes on the origin, diffusion, and domestication of important food-producing crops in the tropics of Old and New World. The utilization of tropical fungi and sea-weeds as sources of human food is briefly discussed. It is concluded that in light of current world food-shortages, improvement of the established tropical food-crops is most necessary at the present time.

INTRODUCTION

Tropical agriculture has greatly expanded during the past hundred years to keep pace with the growth of population and with rising living standards. Preliminary estimates indicate that the increase of 5% in world agricultural production (excluding Mainland China) in 1958-59 was followed in 1959-60 by a rise of about 2%, a little more than the estimated annual population growth of 1.6%. Much attention has, therefore, recently been given to the old Malthusian hypothesis that world population will eventually outstrip world food supply. According to FAO's review of 'The State of Food and Agriculture 1961', there has been little increase in world agricultural production to set against the continuing growth of population. Ecology indicates that the tropical habitat offers the brightest productivity potential of the world at the present time (Holdridge, 1959).

The tropical rain climates or humid tropics occupy a belt about 20° wide on each side of the equator. Here, the temperature is equable and high throughout the year, about 27°C and the rainfall is regular and plentiful. No combination of physical conditions in the world is more favourable to vegetation and its luxuriance and floral abundance has been regarded as "the supreme effort of plant life at this period of the world's development". There are three chief areas of occurrence: in America, Africa, and the Malaysian region. Rain forests occupy lowland areas of Indonesia, and many small islands of the Pacific as well as Ceylon, Australia, Burma, Thailand and Indo-China. In India, the rain forest is found in the Western and Eastern Ghats, and more extensively in the lower part of the Eastern Himalayas and the Khasi hills in Assam (Richards, 1952). The tropical rain forests gradually change into woodland and scrub forests, with scattered trees in a dominant setting of tall grass (the savanna). The trees are small, often thorny and spaced so far apart, giving the vegetation an open appearance. The savanna represents one of the most widespread landscapes of Africa and to a lesser extent in Burma, Siam and Laos. In still drier regions the savanna passes into a more xerophytic type of vegetation—the thorn forest. In parts of Burma and some other sections of southern Asia, monsoon climates are found, producing a semideciduous forest with a very marked seasonal rhythm. The tropical dry lands are found on the west coasts of the continents between about 20° and 30° north and south of the equator. Deficiency in moisture is the basic fact of these lands and under the most arid conditions, these result in the development of deserts (Core, 1955).

WORLD DOMESTICATION CENTRES AND TROPICS

The centres of origin of agriculture were peculiarly restricted. All basic cultivated food plants were domesticated from wild species, both in the Old and New Worlds, long before the dawn of recorded history. The available records indicate that they were as familiar to the people of the ancient world as they are to us and comparatively few new plants have been developed during the last two thousand years. Merrill (1938) believes that in pre-Columbian days agriculture and the civilizations based upon it in America and Eurasia were autochthonous, in that it was based on strictly native plants and animals.. In each region, these centered around a few distinctly important species, such as maize, the garden and lima beans, sweet potato and common potato in America, and wheat, barley, rye, oats, millet, sorghum, rice and other less important cereals, with certain vegetables and fruits in the Asiatic centres.

As early as 1883, Alphonse De Candolle in his classic "L' origine des plantes cultiveé's" stated the ancestral form, region of domestication, and history of most of the important cultivated plants. Later on, Vavilov (1926) assembled immense data on the subject and was able to map out the world domestication centres, in which it was assumed that the area of greatest frequency for related varieties, forms, and strains was the centre of dispersal. It becomes evident from this work that the great centres of distribution of our cultivated crops were always in regions of limited rainfall and mild climate. Neither the humid tropics nor the cold temperate regions have apparently contributed to any food plants of world importance. At the present time the available data seem to establish the following domestication centres within the tropical climates (Ames, 1939; Hutchinson and Melville, 1948; Hill, 1952; Schery, 1954; Blaydes, 1954; Uphof, 1959):

In *south-eastern Asia* the banana, breadfruit, peach, oranges, lemon, rice, soybean, sugarcane, yams, taro, certain millets and various vegetables were domesticated.

The *American tropics* was the home of maize or Indian corn, potato, sweet potato, cassava, all varieties of field and garden beans, as well as the lima, scarlet runner, tepary and yam beans, tomato, Jerusalem artichoke, squash, pumpkin, arrowroot, peanut, custard apple, soursop, cherimoya, guava, cashew, cacao, sapote, white sapote, sapodilla, star apple, mamey, granadilla and malanga (Merrill, 1935, 1936, 1946; Verrill, 1937).

In *Malaysia* the durian, mangosteen, rambutan, pulasan, langsat, and sago palm were native (Merrill, 1946).

Tropical Africa was the centre of dispersal for the water melon, pearl millet, cowpea, kafir potato, bottle gourd, and ragi (Murdock, 1959).

In the humid tropics of western *India*, the jack fruit was indigenous (Jarrett, 1959).

Thus it would appear that the majority of the more important food plants are gifts from the New World tropics. As a matter of fact, the tropical flora is so varied and abundant that the number of the variety of cultigens in the tropics is relatively larger than in the temperate regions.

THE MOVEMENT OF CROPS IN THE TROPICS

Of the several hundred thousand different species of plants now known, only a few hundred are cultivated for food and of these a much smaller number may be considered basic food plants. The number of domestic animals is also very small. And all of these plants and animals were in domestication somewhere in the world long before the dawn of recorded history, whether in Eurasia or in America; but not a single basic cultivated plant and only one domestic animal, the dog, was common to the two hemispheres until after the close of the fifteenth century. It was the expansion of European activities that led to the universal 'diffusion of agriculture' and introduction of Eurasian cultivated plants into America and *vice versa*. Today, as a result of the developments within the past 450 years, we find very many plants of American origin cultivated in India, Africa, Malaysia, Polynesia etc., as we find many of the species of Old World origin now established in the American tropics. It is interesting to note that the world's major tropical plant products are at present produced in countries far removed from their region of origin, e.g. south-east Asian sugarcane, bananas and limes in the West Indies; South American cacao in West Africa etc. Many of the staple crops now grown in parts of tropical Africa are of New World origin, e.g. cassava, sweet potato and maize. In the Malaysian Region, the majority of species important as producers of carbohydrates and fats for the Indonesian diet have been introduced less than a thousand years ago and the greater part is even from post-Columbian times. It appears that many of the more important food plants have been derived from the New World flora. The introduction of many cultigens of minor importance, however, took place in pre-Columbian period and now these are spread from Africa to India and Malaysia, including West Polynesia (Van Steenis, 1947, 1949). Many factors are involved in this, including economics, available land, labour supply, technical skill in processing, together with the favourable factors nature offered here in fertile soil and reasonably good climates for prospering crops.

THE FOOD-PRODUCING CROPS

I. CEREALS

Cereals are the most important sources of plant food for many of the tropical peoples. They have been grown since the dawn of history and every major civilization has been founded on them as the principal source of food. Today their production must be calculated in millions of tons. Wheat (*Triticum* spp.) ranks as the leading bread grain. Although essentially a crop of the temperate zones, it is cultivated most widely in semi-arid areas and is the most economically profitable crop for these areas. Rye (*Secale cereale* Linn.), barley (*Hordeum vulgare* Linn.) and oats (*Avena sativa* Linn.; *A. byzantina* Koch.) are usually cultivated at the higher altitudes and become the staple cereal of the inhabitants. Of the various tropical cereals, the following deserve mention:

MAIZE or INDIAN CORN (*Zea mays* Linn.)—Maize is America's only contribution to the important group of the cereals. This species probably originated in a wild state in the lowlands of tropical South America. Nearly one half of the world's supply of maize is raised in the American tropics, followed by China, the Balkans, Java, South Africa, Italy, the U.S.S.R., and India. It is an important subsistence crop in Africa and Asia, but ninety per cent of commercial production goes to feed livestock. In 1960-61, an exceptional increase of 17 million tons in maize production was recorded in the U.S.A., where the area increased by fifteen per cent. The use of hybrid maize is largely responsible for the remarkable gains in acre yields.

RICE (*Oryza sativa* Linn.)—In tropical countries rice is the pre-eminent cereal and dominates the socio-economic existence. It is presumably of Far Eastern origin, although there have been advocates of an African centre of domestication. It has been estimated that half the world's population subsists wholly or partially upon rice. Ninety-five per cent of the world's crop is produced as well as consumed in the Orient. In contrast to all other cereals, rice can tolerate very high temperatures combined with high humidities and can be grown every year without a decline in yield. These factors have contributed to its historic position as the staple food of millions of people in Asia. In 1960-61 world production of paddy (excluding Mainland China, North Vietnam and North Korea) is estimated at 142 million tons, which is above last year's record level.

WHEAT (*Triticum* spp.)—Wheat is cultivated in all parts of the world where climates are cool and rainfall is moderate. If rice is the staple food of half the world, wheat is the chief sustenance of the other half. Wheat seeds have been discovered from the Indus valley excavations at Mohenjo-daro and the carbonised grains resemble those of *Triticum sphaerococcum* Percival, an endemic species, which is still grown as a grain crop in Punjab and Madhya Pradesh. The centre of origin of breadwheat is probably north-western India along with Afghanistan and India is, therefore, one of the ancestral lands of this essential food-grain. Among other species cultivated in India may be mentioned: *Triticum dicoccum* Schrank, *T. durum* Desf., *T. turgidum* Linn., and *T. aestivum* Linn. The famous New Pusa varieties, N. P. 4, N. P. 6, N. P. 12 and N. P. 165 evolved at the Indian Agricultural Research Institute, New Delhi, are high yielding, fairly resistant to rust and has grain of fine quality.

SORGHUMS (*Sorghum vulgare* Pers.)—The importance of this extremely large group of tropical cereals as a source of food for man and animals is now widely recognized. Over large areas of Africa and Tropical Asia, the grain sorghums form an important part of the diet of the natives, whilst elsewhere, especially in America and parts of Australia, they are used extensively as food for domestic animals. World production of grain sorghum is *ca* 25 million tons annually, largely from China, India, Manchuria and West Africa. Snowden (1936) lists 32 races of cultivated sorghums, of which 11 belong to India and South Asia while the rest are purely African. The principal kinds of grain sorghums known in cultivation are: Durra, Kafir, Milo, Shallu, Kaoliang, Federita and Hegari.

PEARL MILLET (*Pennisetum typhoides* Stapf & Hubb.)—Pearl Millet is grown as a rainy-season crop in India and the African Sudan, and yields a very nutritious flour, with minimum demands for soil and moisture.

FINGER MILLET or RAGI MILLET (*Eleusine coracana* Gaertn.)—Ragi is grown from Indonesia to Northern Africa and is one of India's major crops. It is a heavy yielder, sometimes as much as 1500 lbs. per acre and can stand moderately moist conditions and poor soils.

FOXTAIL MILLET (*Setaria italica* Linn.)—The Foxtail Millet probably originated in India, but is principally cultivated in Japan, China, East Indies, North Africa and U.S.A. It is very drought-resistant.

Other tropical cereals of lesser importance are: Japanese Millet (*Echinochloa frumentacea* Link), Jungle Rice (*E. colonum* Link), Proso Millet (*Panicum miliaceum* Linn.), Little Millet (*P. miliare* Lam.), India Paspalum (*Paspalum scrobiculatum* Linn.), Job's Tears (*Coix lachryma-jobi* Linn.), and Wild Rice (*Zizania aquatica* Linn.).

II. LEGUMES

Legumes are considered next in importance to cereals as sources of human food. They give high-protein seeds and thus provide something of a natural balance to the carbohydrate-rich cereals. Not only do the legumes contribute nitrogenous molecules to man and his domestic animals directly; they also build up the soil by bearing the vital nitrifying bacterial symbionts in root nodules. Throughout the tropics and subtropics, where animal protein is not a normal part of the diet, or where it is still somewhat of an expensive luxury, the grain legumes or pulses for direct human consumption represent a first step away from the predominantly carbohydrate diet provided by a monocultural system of agriculture. At the present time it is particularly in Africa south of the Sahara, that FAO is promoting the improvement of these crops and the extension of the area of cultivation. The principal legumes as food plants are discussed below:

There are a great number of forms, species, and even genera of legumes, popularly termed 'beans', the seeds or pods of which constitute some of mankind's most important foods. The Broad Beans (*Vicia faba* Linn.), Soybeans (*Glycine max* Merr.), and a few other types were well known in the Old World before the times of Columbus, but the choice food beans of the world, the large-seeded species of *Phaseolus*, were the exclusive ward of the New World Indians. Today beans are eaten by countless thousands of tropical inhabitants. World bean production averages an estimated 4 million tons annually, most of which is consumed domestically. Brazil is the largest single producer, followed by the United States.

ADSUKI BEAN (*Phaseolus angularis* Wight)—The Adsuki Bean is widely grown in China and Japan, ranking after the Soybeans.

BROAD BEAN (*Vicia faba* Linn.)—The Broad Bean is probably native to northern Africa and the Near East. It has been cultivated since prehistoric times. Over 100 varieties are grown, chiefly in the Old World.

CHICK PEA (*Cicer arietinum* Linn.)—The Chick Pea is grown principally in India and is well-adapted to semi-arid conditions. It is an important food for the peoples of northern Africa, Spain, and Tropical America as well as India. World production reaches almost 5 million tons, ninety per cent of it from India.

COWPEA (*Vigna sinensis* Savi)—The Cowpea is a very old crop, probably native to Central Africa, although believed by some to have arisen in Central Asia. It has been introduced into the tropics and subtropics of both hemispheres, reaching the West Indies in the seventeenth century and the United States in the eighteenth. The species is much grown in China, India and the southern United States.

GOA BEAN (*Psophocarpus tetragonolobus* DC.)—The Goa Bean, said to be native of Mauritius, is commonly cultivated in the Old and New World tropics.

Another species, *P. palustris* Desv. is cultivated in some parts of Africa.

HYACINTH DOLICHOS or LABLAB (*Dolichos lablab* Linn.)—The Lablab is an important legume in many tropical countries. It is reported to be native to India and has been cultivated since ancient times. The Twinflower Dolichos or Horse Gram (*D. biflorus* Linn.) is widely cultivated in the Old World tropics.

JACK BEAN (*Canavalia ensiformis* DC.)—The Jack Bean, a native of the West Indies, is cultivated in almost all tropical countries, and to a considerable extent in South America. Another species, *C. gladiata* DC. (Sword Bean), native of India, is widely cultivated throughout the East.

KIDNEY BEAN (*Phaseolus vulgaris* Linn.)—This very valuable species is native to tropical America, possibly Brazil. It is the most widely cultivated of the beans.

LENTIL (*Lens culinaris* Medic.)—The Lentil, believed to be indigenous to south-western Asia, is one of the oldest food plants. It constitutes an important food in Asia, particularly India.

LIMA BEAN (*Phaseolus lunatus* Linn. Syn. *P. limensis* Macf.)—The Lima Bean has been called the aristocrats of the bean family. It is a native of Peru, Brazil and Guatemala, and has been grown in South America for centuries.

MOTH BEAN (*P. aconitifolius* Jacq.)—The Moth Bean is widely cultivated in India; presumably recently domesticated.

MUNG BEAN (*P. aureus* Roxb.)—The Mung Bean is one of the very ancient legumes of India and is still an important crop. Over a hundred kinds are grown in China and other Asiatic countries.

MUNGO BEAN or URD BEAN (*P. mungo* Linn.)—The Mungo Bean is extensively grown in India and the East. It is probably native to India.

PEAS.—The Garden Pea, *Pisum sativum* Linn., was probably domesticated in Central Asia, with possibly secondary developments in the Near East and North Africa. World production of Field Peas (*P. arvense* Linn.) amounts to approximately 5 million tons; the principal regions are North America and Eurasia.

PEANUT (*Arachis hypogaea* Linn.)—The Peanut, an ancient gift from South America, was early carried to the Old World tropics by the Portuguese explorers and is now grown extensively in India, East and West Africa, China and Indonesia. World production averages about ten million tons of peanuts annually.

PIGEON PEA (*Cajanus cajan* Millsp.)—The Pigeon Pea is one of the most promising legumes at the present time. It is widely grown in tropical and subtropical countries, particularly India, Equatorial Africa, and the East and West Indies.

RICE BEAN (*Phaseolus calcaratus* Roxb.)—The Rice Bean, native to south-eastern Asia, is cultivated to a limited extent in China, Japan, India, and the Philippines.

SOYBEAN (*Glycine max* Merr.)—The Soybean is one of the oldest crops grown by man. It is a native of Eastern Asia, where over 1000 varieties are grown. Since ancient times soybeans have been consumed directly as food in Asia. World production exceeds 15 million tons annually (Lager, 1945).

YAM BEAN (*Pachyrrhizus tuberosus* Spreng.)—The Yam Bean, a native of Tropical America, is now widely cultivated and naturalized throughout the world tropics. It provides edible tubers and pods. *P. erosus* Urban (Sincama), native to Central America, has been similarly spread and utilized for its turnip-like roots. *P. bulbosus* Spreng., probably from Tropical Asia, is also cultivated in tropics of Old and New World.

Other tropical legumes of lesser importance are: Guar (*Cyamopsis tetragonoloba* Taub.), Grass Pea (*Lathyrus sativus* Linn.), Congo Goober (*Voandzeia subterranea* Thon.), Tepary Bean (*Phaseolus acutifolius* Gray var. *latifolius* Freem.), Scarlet Runner Bean (*P. coccineus* Linn.), and Thicket Bean (*P. polystachyus* B. S. P.).

III. VEGETABLES

(ROOT, STEM, LEAF AND FRUIT CROPS)

Vegetables constitute a large and varied group of considerable importance in the world's commerce. They can be grown in all parts of the tropics where any other cultivation is possible, but are suited chiefly to low or intermediate elevations. While certain temperate vegetables such as beetroot, celery, parsnips, leeks, carrots, rhubarb, broccoli, cabbages, cauliflower, asparagus, brussels sprouts, kohlrabi, onions, lettuce, globe artichoke, salsify, spinach, turnip, vegetable marrow etc. thrive almost to perfection in the cool moist climate of the higher elevations in tropics, several of these may also be grown at lower altitudes, or even at sea-level, with some degree of success if sown at suitable seasons and supplied with the necessary amount of moisture and shade. The principal kinds of tuber, leaf and fruit crops cultivated in the tropical regions are listed below (Thompson and Kelly, 1957):

ARROWROOT—The tuberous rhizomes of several tropical plants yield arrowroot, which is much used in foods for invalids and children. Bermuda Arrowroot comes from *Maranta arundinacea* Linn., native of Tropical America, now much cultivated in most tropical countries. This is chiefly obtained from the West Indies, notably Bermuda and St. Vincent, where the plant is systematically cultivated. Edible Canna or Queensland Arrowroot from *Canna edulis* Ker-Gawl, indigenous to Tropical America, is cultivated in tropics, among which especially West Indies and Hawaii. The yield under favourable conditions, is estimated at about 5 to 8 tons of tubers per acre. Fiji Arrowroot from *Tacca pinnatifida* Forst., indigenous to the Eastern tropics is commonly cultivated in India, Ceylon, Tropical Africa, Fiji, Hawaii etc. East Indian Arrowroot is obtained from *Curcuma angustifolia* Roxb., indigenous to the Himalayan region; sometimes also called Travancore Starch. Mahabaleshwar Arrowroot is obtained from the tubers of *Hitchenia caulina* Baker, occurring wild on the Mahabaleshwar plateau (India) and extending downwards on the west coast (Santapau *in litt.*).

CASSAVA (*Manihot esculenta* Crantz.)—The Cassava, next to the sweet potato, is the most important of the tropical root-crops and furnishes the basic food for millions of tropical peoples in Latin America, Africa and the Far East. It is a native of South America, but is widely grown in all tropical and sub-tropical regions; particularly important in hot tropical, often seasonally arid climates where cereals and potatoes will not grow well.

JERUSALEM ARTICHOKE (*Helianthus tuberosus* Linn.)—This is one of the most successfully cultivated of temperate vegetables in the tropics, where it often thrives better in the low country than at the higher elevations.

MALANGA—(*Xanthosoma sagittiaefolium* Schott), The Yautia Malanga, a native to the New World tropics, is of local importance for food in both America and Africa. *X. violaceum* Schott. (Primrose Malanga) from Tropical America, is cultivated in tropics of Old and New World.

POTATO (*Solanum tuberosum* Linn.)—The Potato, a gift of the Andean highlands of South America, is one of the most important food plants of the world. It is, however, one of the most difficult crops to grow on account of the many fungal and virus diseases. Very fair crops of potatoes can be grown at the higher elevations in the tropics. At Bangalore, India, two crops a year can be obtained, and at some of the hilly stations in India and elsewhere in the tropics, excellent potatoes are produced almost all the year round. In yield, however, potato crops in the tropics are seldom comparable to those of temperate countries.

SWEET POTATO (*Ipomoea batatas* Poir.)—The Sweet Potato, a gift of the New World, is one of the richest plant foods and is high not only in carbohydrates but in vitamins and minerals. It has been highly prized in the Orient since late in the sixteenth century, when it was introduced to China to relieve famine. Nearly half of the 10 million metric tons of sweet potatoes produced in the world each year are grown in Japan. In many tropical islands sweet potatoes are grown in every garden and constitute an important part of the family food.

TARO (*Colocasia esculenta* Schott & Endl.)—The Taros are plants of very moist tropical countries, where it is cultivated extensively as a leafy vegetable and for the edible tubers. Formerly, before the introduction of potatoes, taro was more generally used.

YAMS (*Dioscorea* spp.)—The cultivated species of *Dioscorea* are indigenous to the tropics. Except for sweet potatoes and cassava, they are probably the most used of tropical lowland root-crops in Tropical America, Africa, the Pacific Islands and south-eastern Asia. In addition to *D. alata* Linn. (Winged Yam), there are cultivated in Africa: *D. bulbifera* Linn. (Air Potato Yam), *D. esculenta* Burk. (Chinese Yam), *D. dumetorum* Pax, and *D. cayenensis* Lam. (Attoto Yam); in the Orient: *D. esculenta* Burk. (Chinese Yam), *D. divaricata* Blanco, *D. pentaphylla* Linn., *D. oppositifolia* Linn.; and in Tropical America: *D. trifida* Linn. f. (Cushcush Yam) and *D. cayenensis* Lam. (Attoto Yam). However, all these species contain the alkaloid dioscorine, which is a dangerous principle, somewhat similar in action to strychnine. It is, therefore, only after repeated boiling in salt water alternating with boiling in fresh water can these tubers be safely eaten. The importance of *Dioscorea* has been much reduced after the introduction of potatoes into the tropics.

Other tropical tuber-crops of restricted importance are: Edible Calathea (*Calathea allouia* Lindl.), West Indies; Chufa Tigernut (*Cyperus esculentus* Linn.), pantropics; Oka (*Oxalis crenata* Jacq.), Peru; Tuber Nasturtium (*Tropaeolum tuberosum* Ruiz. & Pav.), Peru; Arracacia (*Arracacia xanthorrhiza* Baner.), South America; Hausa or Fra-Fra Potato (*Coleus rotundifolius* Chev. & Perrot.), Africa, Malaysia and East Indies; Kafir Potato (*C. dazo* Chev.), Congo, Sudan; Tuber Ullucus or Melloco (*Ullucus tuberosus* Caldas.), South America; Arikuma (*Polymnia sonchifolia* Poepp. & Endl.), Peru; Gamote or Wild Parsnip (*Phellopterus montanus* Nutt.), Mexico; Sandroot (*Ammobroma sonorae* Torr.), Mexico; Carib Heliconia or Wild Plantain (*Heliconia bihai* Linn.), Tropical America; and Madeira Vine (*Boussingaultia gracilis* var. *pseudobaselloides* Bailey), Tropical America.

BALSAM PEAR (*Momordica charantia* Linn.)—This is an African species, extensively cultivated in all tropical and subtropical countries.

CALABASH GOURD or BOTTLE GOURD (*Lagenaria siceraria* Standl.)—The Calabash Gourd has been cultivated since ancient times. It probably originated in Africa and is among the most popular of vegetables, commonly cultivated in the tropics.

CHAYOTE (*Sechium edule* Sw.)—The Chayote, native of Tropical America where most production is locally consumed, has recently become one of commercial importance. It is suited to the higher elevations in the tropics, and is also commonly cultivated in the subtropics.

CUCUMBER (*Cucumis sativus* Linn.)—The Cucumber, presumably indigenous to South Asia, is a hot weather species; now cultivated in Old and New World. *C. anguria* Linn., the West Indian Gherkin of American tropics, and *C. metuliferus* E. Mey., of Tropical Africa are also cultivated in these regions.

EGG PLANT (*Solanum melongena* Linn.)—The Egg Plant is a native of India, but is widely grown in the warmer regions of both hemispheres, especially in the West Indies and Southern United States.

LOOFAH or SUAKWA VEGETABLE SPONGE (*Luffa cylindrica* Roem.)—The Loofah, indigenous to Tropical Africa and Asia, is cultivated in the tropics of the Old and New World. *L. acutangula* Roxb.—The

Singkwa Towelgourd, from Tropical Asia is cultivated in some parts of China and Japan.

MUSKMELON (*Cucumis melo* Linn.)—The Muskmelon, probably from South Asia and Tropical Africa, is cultivated in Old and New World ; especially suited to warmer climates.

OKRA (*Abelmoschus esculentus* Moench)—Okra is believed to have originated in the north-east African centre of domestication and has now been introduced into most warm tropics and subtropics.

SNAKE GOURD (*Trichosanthes anguina* Linn.)—The Snake Gourd, indigenous to Tropical Asia, is commonly cultivated in the tropics. *T. dioica* Roxb., indigenous to India, is cultivated in Assam, Bengal, Bihar and U.P.

SQUASH (*Cucurbita maxima* Duch.)—The Squash, probably from America, is commonly grown throughout the tropics. It is considered as one of the best of tropical vegetables, being easily cultivated and giving quick and heavy yields. *C. moschata* Duch., the Cushaw, and *C. pepo* DC., the Pumpkin, are also cultivated on a small scale.

TOMATO (*Lycopersicon esculentum* Mill.)—The Tomato, native of Tropical America, is commonly grown in all warm countries. It can be grown with much success in the tropics, especially in rather dry districts and at medium elevations.

WAX GOURD (*Benincasa hispida* Cogn.)—The Wax Gourd, indigenous to the Old World tropics, is today grown in all warm countries. It will thrive in sheltered valleys up to about 1220 m.

Among other vegetables of restricted importance may be mentioned: Downy Groundcherry (*Physalis pubescens* Linn.), Devils Claws (*Proboscidea jussieui* Steud.), Casabanana (*Sicana odorifera* Naud.), Love-lies-bleeding (*Amaranthus caudatus* Linn.), Josephs-Coat Amaranth (*A. tricolor* Linn.), *A. mangostanus* Linn., Vine Spinach (*Basella alba* Linn., *B. rubra* Linn.), *Ipomoea reptans* Poir., Agati (*Sesbania grandiflora* Pers.), purslane (*Portulaca oleracea* Linn.), and Cabbage Palms.

IV. FRUITS

The number of edible tropical fruits is multitudinous. Thousands of them are used daily by the tropical peoples and fruits are among the best products that the tropics have to offer to mankind. There are 250 edible fruits in the Philippine Islands alone and many more are potentially available for use, although still coming from the tropical jungles. Sooner or later, the people of the temperate regions will have to turn to a great extent to the tropics to supplement their own food resources. The well-known tropical fruits are mentioned below (Dahlgren, 1947):

AVOCADO (*Persea americana* Mill.)—The Avocado is native to the tropical American lowlands and has assumed much importance in the tropical diet, on account of its rich source of digestible fats and proteins. Today it is commonly grown in the Eastern tropics, as well as in Florida, Mexico, Queensland, Madeira, Natal etc. (Hodgson, 1950).

BANANA (*Musa paradisiaca* Linn.)—The edible bananas are among the foremost of tropical foods, grown in almost all moist regions of the tropics. About thirty species and subspecies of *Musa* are said to yield edible bananas and present world production is more than 11 million tons annually. From its original home in the humid tropics of India or Malaya, it has now spread all over the tropical world. About three-fourths of the world production of bananas comes today from the American tropics. Chief growing centres are Tanganyika and French Guinea in Africa ; Mexico, Honduras, Brazil and Colombia in the Americas ; India ; the West Indies ; the Philippines ; the Canary Islands ; Fiji and Australia. The Plantain (*M. sapientum* Linn.), a close relative of the banana, is cultivated in many tropical countries. A native of southern Asia, it has furnished food for all tropical peoples for centuries.

BREADFRUIT (*Artocarpus communis* Forst.)—The Breadfruit, native of Malaysia, has spread throughout the tropical lowlands of the world. It is a staple in the diet of Pacific Island peoples and is here and there cultivated in the New World tropics. Another species, *A. heterophyllus* Lam. (Jack fruit), indigenous on the Western Ghats of India, is also widely dispersed in the tropics. The fruits and seeds are much consumed in the tropics (Jarrett, 1959).

CUSTARD APPLES—Many of the tropical representatives of the Annonaceae produce edible fruits and afford great promise for future development. The true Custard Apple (*Annona reticulata* Linn.) is native of the West Indies and the tropical American mainland. It is cultivated in tropics of Old and New World. The Cherimoya (*A. cherimola* Mill.) originated in the Andes of Peru and Ecuador, and now grown here and there throughout the tropics. The Sugar Apple (*A. squamosa* Linn.), native of South America and the West Indies, is now widely cultivated throughout the tropics. The Soursop (*A. muricata* Linn.) of the West Indies, is cultivated in tropics of Old and New World. The Atemoya (*A. atemoya* Hort.) produces good crops in South Florida.

DATE (*Phoenix dactylifera* Linn.)—The Date, probably indigenous from Arabia to India, is cultivated since time immemorial. It is grown in tropical semi-arid desert regions of the Old and New World, and has been successfully established in California, Arizona, Queensland, Northern India etc. It is particularly adapted to the oases of North Africa and Arabia, where it is the only crop of any significance.

DURIAN (*Durio zibethinus* Murr.)—The Durian, indigenous to Malaya, has been for centuries a favourite fruit source in the Malaya area, Burma and the East Indies. It has been introduced in tropics of the New world (Kostermans, 1958).

GRANADILLA (*Passiflora* spp.)—The Granadillas are native to the Americas, but have found greatest popularity in Australia and the Far East. The Purple Granadilla (*Passiflora edulis* Sims.), a native of Brazil, is cultivated in tropics and parts of subtropics of Old and New World; occasionally exported from Australia and South Africa. Other common species include, the Sweet Granadilla (*P. ligularis* Juss.); the Giant Granadilla (*P. quadrangularis* Linn.); Waterlemon (*P. laurifolia* Linn.); and the Tasco (*P. mollissima* Bailey; *P. tripartita* Poir.).

GUAVA (*Psidium guajava* Linn.)—The Guava, sometimes called the 'apple of the tropics', is another tropical American fruit that has been cultivated for centuries. Today it is common throughout the tropical lands, where it often becomes naturalized (Ruehle, 1948; Rangacharlu, 1954). World production of guava must certainly amount to several hundred thousand tons annually, most of which is consumed locally. The Cattley Guava (*P. cattleianum* Sab.), a native of Brazil, is cultivated elsewhere in tropics and subtropics. Other species, occasionally cultivated in tropics are: Brazilian Guava (*P. araca* Raddi), *P. fluviatile* Rich., Costa Rican Guava (*P. friedrichsthalianum* Ndz.) and Guisaro Guava (*P. molle* Bertol.).

JUJUBE (*Zizyphus jujuba* Mill.)—The Jujube is a native of China and can be grown in all tropical and subtropical countries. The Indian Jujube (*Z. mauritiana* Lam.) is also widely cultivated in tropical parts.

LIME (*Citrus aurantifolia* Swingle)—The Lime was domesticated in the East Indies and takes the place of the lemon in the tropics. It is very susceptible to cold and is a distinctly tropical plant. Limes are grown as a commercial product in Mexico, the West Indies and Florida, where they form an important industry.

LOQUAT (*Eriobotrya japonica* Lindl.)—The Loquat, a native of South China and Japan, is cultivated in most warm countries, being suited to medium elevations in the tropics. It is perhaps the most important of the limited selection of rosaceous fruits for the tropics.

LYCHEE (*Litchi chinensis* Sonner.)—This famous and prolific tree of Southern China has been in cultivation in the Far East since time immemorial. It is now widely grown in the tropics and has been introduced into American tropics. The Rambutan (*Nephelium lappaceum* Linn.) of Malay Archipelago; the Pulasan (*N. mutabile* Blume) of Malay, Java and Borneo; and the longan (*Euphoria longan* Steud.) of China, all relatives of the lychee, are cultivated in the Eastern tropics.

MANGO (*Mangifera indica* Linn.)—This Eastern Asiatic species is one of the most important of tropical fruits and is cultivated throughout the tropics in numerous horticultural varieties. The Mango is the fruit *par excellence* of India and is eaten by millions of people. The total production is estimated to be over hundred thousand tons.

MANGOSTEEN (*Garcinia mangostana* Linn.)—The Mangosteen, regarded as native of Moluccas, is generally considered to be the world's most delicious fruit, and is highly prized in regions where it can be grown. It has long been termed the 'queen of tropical fruits' and is common in the East Indies and Malaysia. Other species, occasionally cultivated in tropics are: *G. cambogia* Desr., *G. xanthochymus* Hook. f., *G. atroviridis* Griffith, *G. dulcis* Kurz, *G. hombroniana* Pierre, and *G. indica* Choisy. The Mamey (*Mammea americana* Linn.), a close relative of the garcinias, is an important edible fruit in the West Indies and Tropical America, and seems to be a promising fruit for the Old World tropics.

OLIVE (*Olea europaea* Linn.)—The Olive is primarily a crop of the Mediterranean area, but has been widely introduced throughout the tropics and subtropics. In Queensland, South Africa and Northern India, it has become well established and bears fruit abundantly. World production reaches about 4 million tons.

ORANGES—The Sweet Orange (*Citrus sinensis* Osbeck.), considered to be a native of China or Indo-China, has long been cultivated in all warm countries, and to the greatest perfection in the subtropics. It thrives, however, in the tropics, growing at low and medium elevations in numerous varieties. Oranges are extensively cultivated for export in various subtropical countries, as southern United States, South Africa, Australia, Palestine, West Indies etc. The Sour Orange (*C. aurantium* Linn.), sometimes known as bitter, bigarade, marmalade, or Seville Orange, is a native of south-eastern Asia. It is widely cultivated and bears well in tropics at medium elevations. The Mandarin Orange (*C. reticulata* Blanco), said to have originated in China or Indo-China, is well known in tropics of the Old and New World, under the following varietal groupings: King, Satsuma, Tangerine, Mandarin, Mitis, Nagpur Suntra, and Suntara. The main commercial producers are U.S.A. (with about half the total output), Brazil, Spain, Italy, Japan and Israel. World production of citrus fruits is likely to exceed 20 million tons annually.

PAPAYA (*Carica papaya* Linn.)—The Papaya is found wild and naturalized through most of Tropical America. As early as 1598 it had been introduced into India, and soon after it spread through the Pacific Islands, where today it is common and much esteemed. Considerable Papaya is exported from Ceylon to the New World.

PINEAPPLE (*Ananas comosus* Merr.)—The Pineapple, unlike the banana and the citrus fruits, is a gift of the tropics of the Western Hemisphere. It was carried by the Spaniards and Portuguese to the Old World, and spread all over Tropical Asia, Africa, the East Indies and Polynesia. Today it constitutes a first-rank agricultural import of temperate regions. The chief commercial producing countries are: Hawaii, Brazil, Cuba, Mexico, Malaya, Formosa, Australia and South Africa.

POMEGRANATE (*Punica granatum Linn.*)—The Pomegranate is a native of Iran and now naturalized in the Mediterranean area and southern Asia. It has been widely introduced in arid tropical and subtropical regions of America, but is more popular in the Old World (Evreinoff, 1949).

PUMMELO or SHADDOCK (*Citrus maxima* Merr.)—The Pummelo, a native of Malaya and Polynesia, is commonly cultivated throughout the tropics. It grows luxuriantly in the moist lowlands and thrives up to about 1220 m. The Grapefruit (*C. paradisi* Macf.), possibly a hybrid or sport of the closely related Pummelo, has now become well known in the tropics. U.S.A. is by far the largest producer; other countries of importance are Israel, Jamaica, Puerto Rico and South Africa.

Among other citrus fruits may be mentioned: Lemon (*C. limon* Burm. f.); Citron (*C. medica* Linn.); Sweet Lime (*C. limetta* Risso.) and Kumquat (*Fortunella japonica* Swingle ; *F. margarita* Swingle).

SAPODILLA (*Achras zapota* Linn.)—The Sapodilla is one of the best dessert fruits of Tropical America, and is today planted throughout the world tropics. Among other edible plants of the Sapotaceae may be cited: the Sapote (*Calocarpum mammosum* Pierre) of Central America; the Star Apple (*Chrysophyllum cainito* Linn.) of West Indies; the Canistel Lucuma (*Lucuma rivicoa* Gaertn. f.) of South America; and White Sapote (*Casimiroa edulis* Llave) of Central America, all of considerable importance.

TAMARIND (*Tamarindus indica* Linn.)—The Tamarind probably originated in Tropical Africa or southern Asia and is now firmly established throughout the world tropics.

Other tropical fruits of minor or restricted importance and of some renown are: Ambarella (*Spondias cytherea* Sonn.); Andaman Mombin (*S. pinnata* Kurz); Caja (*S. lutea* Linn.); Purple Mombin (*S. purpurea* Linn.); Kaki Persimmon (*Diospyros kaki* Linn. f.); Bilimbi (*Averrhoa bilimbi* Linn.); Carambola (*A. carambola* Linn.); Ramontchi (*Flacourtia indica* Merr.); Natal Plum Carissa (*Carissa grandiflora* DC.); Tree Tomato (*Cyphomandra betacea* Sendt.); Naranjilla (*Solanum quitoense* Lam.); Akee (*Blighia sapida* Koen.); Bakuri Guiana Orange (*Platonia insignis* Mart.); Capulin Blackcherry (*Prunus capóllin* Koehne); Cashew (*Anacardium occidentale* Linn.); Ceriman (*Monstera deliciosa* Liebm.); Rose Apple (*Syzygium jambos* Alston); Ohia (*S. malaccense* Merr. & Perry); jambolan (*S. cumini* Skeels); Genip (*Genipa americana* Linn.); Otaheite Gooseberry (*Phyllanthus acidus* Skeels); Coco Plum (*Chrysobalanus icaco* Linn.); Inga ; Marang (*Artocarpus odoratissima* Blanco); Lakoocha (*A. lakoocha* Roxb.); Langsat (*Lansium domesticum* Jack.); Mamoncillo (*Melicocca bijuga* Linn.); Brazil Nut (*Bertholletia excelsa* H. B. K.); Sawari Nut (*Caryocar nuciferum* Linn.); Watermelon (*Citrullus vulgaris* Schrad.); Monkeypot Tree (*Lecythis zabucajo* Aubl.); Baelfruit (*Aegle marmelos* Correa); Rambeh (*Baccaurea motleyana* Muell.-Arg.); *Peach Palm* (Bactris *gasipaës* H.B.K.); Java Almond (*Canarium commune* Linn.); Nam-nam (*Cynometra cauliflora* Linn.); Velvet Tamarind (*Dialium ovoideum* Thw.); woodapple (*Limonia acidissima* Linn.); Spinach Jointfir (*Gnetum gnemon* Linn.); Bayberry (*Myrica nagi* Thunb.); Manguiera-a-grappes (*Sorindeia madagascariensis* DC.); Tropical Almond (*Terminalia catappa* Linn.); Water Chestnut (*Trapa bicornis* Linn.; *T. natans* Linn.); Singhara nut (*T. bispinosa* Roxb.); Feijoa (*Feijoa sellowiana* Berg.); Chinese Pear (*Pyrus pyrifolia* var. *culta* Nakai); Cacao (*Theobroma cacao* Linn.); Peruvian Groundcherry (*Physalis peruviana* Linn.); Fig (*Ficus carica* Linn.); and Mulberry (*Morus alba* Linn.; *M. nigra* Linn.).

V. OTHER FOOD PLANTS

COCONUT (*Cocos nucifera* Linn.)—'Man's most useful tree', the Coconut, presumably native to the Old World, has been scattered by sea currents throughout the coastal areas of all oceans. Today it dots the shores of all tropical lands and the fruit is often a main source of food among island people. Moreover, it has been widely planted within the last century, and most production today comes from planted groves in the Far East. The Coconut is essentially a tropical plant and thrives best within the true tropics. Under good plantation conditions, this is one of the most productive crops. World production, in terms of copra, is about two and two-half million tons annually (Cook, 1901; Beccari, 1917; Mayuranathan, 1938).

SAGO (*Metroxylon sagu* Rottb.)—The Sago Palm of the tropics, is cultivated in Malaya and Indonesia, and yields the most common sago starch. Another species, *M. rumphii* Mart. of Malaysia, is also cultivated in the tropics of the Old and New World. In India, at least in times of scarcity sago is obtained from the trunk of *Caryota urens* Linn.

SUGARCANE (*Saccharum officinale* Linn.)—The Sugarcane is essentially a perennial plant of the warm tropics and optimal yields are obtained when frequently heavy rainfall is interspersed with bright sunshine, which ensures that during the period of maturity, the rate of sugar accumulation is maximal. Apparently indigenous to south-eastern Asia and the Eeast Indies, it has been spread throughout the Old and New World tropics. The chief countries of cane-sugar production now are: India, Java and Cuba. It is also grown on an extensive scale in the Guianas, Hawaii, Fiji, Philippines, Brazil, Puerto Rico, Australia and East Africa. Today sugarcane is the greatest export crop of the tropics. World production of centrifugal sugar in 1959-60, excluding Mainland China, is estimated at 48.4 million tons.

SUGAR PALM—Palm sugar of jaggery is obtained from the sap of several species of palm and is available only in the tropics. The palm sugar industry of India and the Eastern tropics is an old one and produces about a hundred thousand tons annually. The chief species utilized are: the Sugar Date (*Phoenix sylvestris* Roxb.) of India; the Palmyra Palm (*Borassus flabellifer* Linn.) of Tropical Asia; the Toddy Palm (*Caryota urens* Linn.) of Indo-Malaysia; and the Gomuti Palm (*Arenga pinnata* Merr.) of Malaysia (Dahlgren, 1944).

THE UTILIZATION OF LOWER PLANTS AS FOOD

Since ancient times edible wild mushrooms have been a table delicacy and still today few foods command more respect than the truffles (Tuberales) of France and the morels (*Morchella*) of North America. Today mushroom cultivation has sprung a major industry in the United States, France and England. Many of the tropical fungi growing naturally on the soil or on decayed tree trunks, are edible and play a very important part in native foodstuffs. However, our knowledge of their processes is extremely scanty and many of them need to be accurately investigated, cultivated, hybridized and segregated in order to give them their optimal efficiency.

The use of marine algae as sources of human food is also very ancient in the tropics. In Japan, China, Malaya, parts of Pacific coast of the U.S.A., Burma, Siam, Borneo and Hawaii, many sea-weeds are used as items of food. The nutritive value of algae is high. They have a high carbohydrate and vitamin content, and contain a greater variety of mineral salts than any other food. Since the world presents an even greater surface of water than of land, and ocean, sea, lake and river are endowed with an abundant and characteristic flora, their utilization today becomes of paramount importance. The following marine algae occurring in the tropical seas are utilized as food in the Philippines, Hawaiian Islands, Malay, Moluccas, Amboina, Singapore, Vietnam, Australia, Java, Bali, Burma, Ceylon, and other parts of south-east Asia: *Caulerpa, Chaetomorpha, Codium, Enteromorpha, Ulva, Choospora, Hydroclathrus, Dictyota, Padina, Sargassum, Turbinaria, Porphyra, Acanthophora, Agardhiella, Bostrychia, Caloglossa, Catenella, Corallopsis, Eucheuma, Gelidiella, Gelidium, Gigartina, Gracilaria, Grateloupia, Halymenia, Hypnea, Gymnogongrus, Laurencia, Liagora,* and *Sarcodia* (Zaneveld, 1959; Botanica Marina, 1959). In addition, one cannot ignore the direct benefit of algal micro-organisms in potentially valuable 'microbial farming' in the tropics. During recent years, the unicellular green alga *Chlorella* and the food yeast have been considered as potential sources of food, giving yields considerably higher than that for most crop plants.

CONCLUSIONS

The great diversity of food-producing crops in the tropics is a striking fact. Many of them need taxonomic revision for adequate research. It has been realized that in countries situated in the tropics and subtropics, crop improvement is most necessary at the present time. There is hardly one of the established tropical food-crops in which new genes from wild species and primitive forms are not required to increase yields, improve resistance to pests and diseases, or to extend the zones of adaptability. The cultivated bananas have demanded extensive botanical exploration in the last 20 years to collect as many wild species of its genus *Musa* as could be obtained. So also is the case with Solanaceous fruits, particularly of Tropical America. It has been estimated that half of the total forest area of the world, totalling some 3,638 million acres, is of the tropical type (Zon and Sparhawk, 1923; Paterson, 1956). This forest constitutes the world's greatest reserve of plant wealth at the present time, a fraction of the earth's surface that yet remains primeval, unravaged by man's most cruel axe. However, much work remains to be done for an accurate appraisal of the tropical forests, oceans, and agricultural systems. The virgin forests of the Amazon Hylaea, Central Borneo, New Guinea and other regions of the tropical prototype are yet to be exploited and explored. On first observing the tropical scene, one is overwhelmed by the richness and complexity of the plant life. In fact, there is always available a considerable number of plants with parts that may safely be eaten and one can possibly subsist or at least maintain life for considerable periods of time, provided one knows what to select and how to prepare it. A large variety of these so-called 'jungle or native foods' with which the life of various tropical peoples is closely associated, merit exploitation and domestication. Tropical botany has, in the author's opinion, much to contribute to the necessities of mankind. One of the great students of tropical botany has rightly said: 'Tropical countries inherit a rich share of plant evolution, which has yet to be incorporated into the wisdom, practice and enjoyment of civilization'.

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